Non-standard interactions and LBNE

LBNE-BNL Grp Mtg 1/8/10

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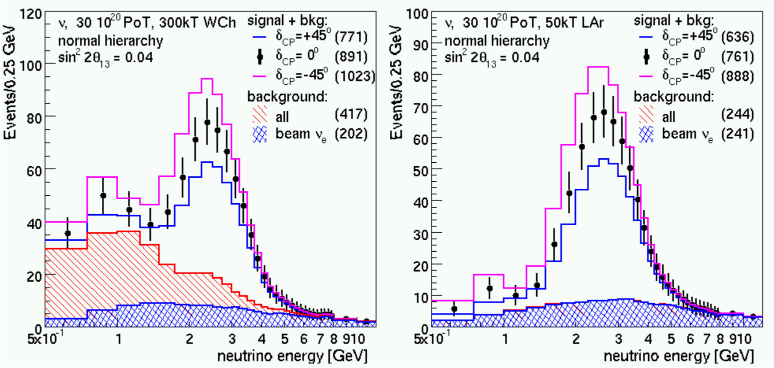
Outline

LBNE/DUSEL spectra and event rates

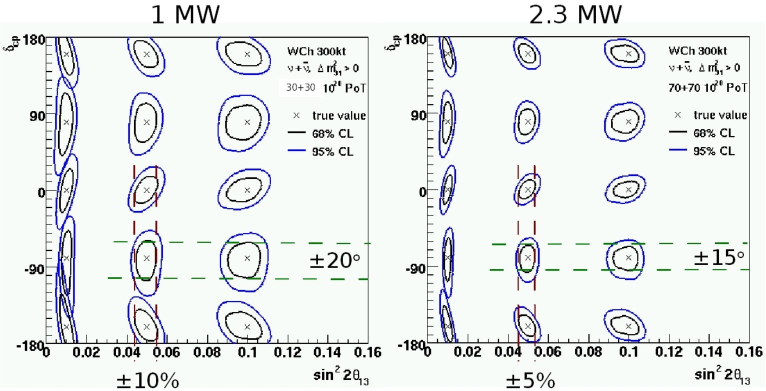
A preliminary on-axis wide-band beam for LBNE based on the NuMI focusing system has been developed. Water Cerenkov response is based on the SuperK MC. LAr is modeled as a near-perfect detector.
Exposure is 3 MW. yr ν with $\sin^2 2\theta_{13} = 0.04, \ \delta_{cp} > 0, \ m_3 > m_1$

300 kT WCe **50 kT LAr**



with a 300 kT WCe detector and 3 yrs of ν + 3 yrs of $\bar{\nu}$ running:

$(\theta_{13}, \delta_{cp})$ Measurement

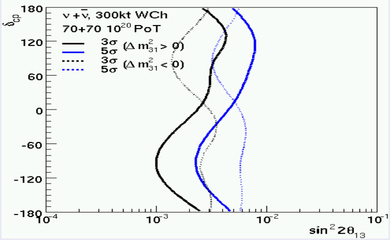


Precision measurement of δ_{cp} for $\sin^2 2\theta_{13} \geq 0.01$

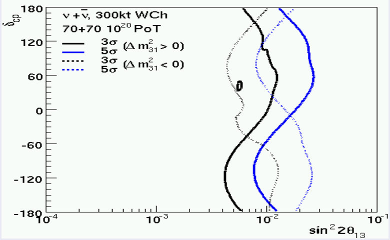
LBNE Sensitivities

WCe, 2.3MW beam, 3 yrs ν + 3 yrs $\bar{\nu}$

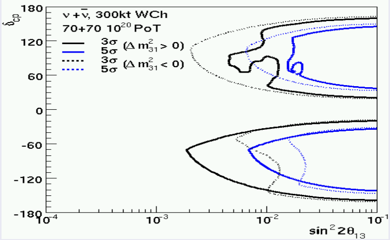
θ_{13} @ 3,5 σ



Mass hierarchy @ 3,5 σ



CP violation @ 3,5 σ



Summary of sensitivities

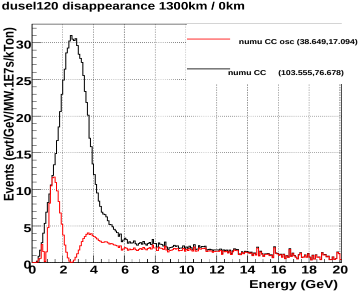
The smallest value of $\sin^2 2\theta_{13}$ @ 3σ:

$\theta_{13} \neq 0$	sign(Δm^2) all δ_{cp}	CPV $50\%\delta_{cp}$
0.004	0.014	0.012

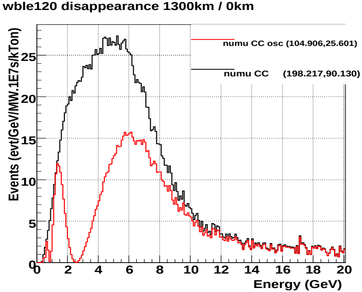
Mark Dierckxsens, APS 09

Precision measurements of ν_τ appearance

NuMI-like beam (LBNE default)



AGS-like HIGH ENERGY beam



AGS-HE beam rates: ν_μ rates: 40,000 unosc CC/100kT/MW.yr (10^{21} POT), 21,000 osc CC/100kT/MW.yr

We expect 420 ν_τ CC/100kT/MW.yr

- **For a smaller LAr detector we can see 100's of ν_τ appear (compared to 3-4 events in DONUT and $\sim$ 10? in OPERA)**
- **For water Cerenkov ν_τ QE interactions followed by $\tau \to \mu$, e will produce an excess of QE-like μ or e events at $>$ 3.2 GeV energies.**

Interaction rates with different beams

Rates/100kt/MW.yr for $\sin^2 2\theta_{13} = 0.04$:

Beam	ν_μ CC	ν_μ osc.	ν_e CC beam	$\nu_\mu \to \nu_e$	$\nu_\mu \to \nu_\tau$
AGS 120 380m on-axis	40K	21K	380	560	420
NuMI 120 380m on-axis	23K	9.0K	260	460	140
NuMI 120 280m on-axis	21K	7.8K	220	400	120
NuMI 60 280m on-axis	18K	5.4K	180	400	40

Even wide-band *high energy* beams produce large ν_e appearance rates.

CPV sensitivity is worse but could expand other physics possibilities

Perhaps we should plan to run with HE some of the time....

Neutrino oscillations including NSI

$$P_{\nu_\alpha^s \to \nu_\beta^d} = |\langle \nu_\beta^d | e^{-i(H+V_{\mathrm{NSI}})L} | \nu_\alpha^s \rangle|^2 = |\langle \nu_\beta^d | (1+\varepsilon^d) e^{-i(H+V_{\mathrm{NSI}})L} (1+\varepsilon^s) | \nu_\alpha^s \rangle|^2$$

- CC type NSI: Flavour mixture at source and detector (Grossman PL **B359** (1995) 141)

$$|\nu_\alpha^s\rangle = |\nu_\alpha\rangle + \sum_{\beta=e,\mu,\tau} \varepsilon_{\alpha\beta}^s |\nu_\beta\rangle, \qquad \text{e.g. } \pi^+ \xrightarrow{\varepsilon_{\mu e}^s} \mu^+ \nu_e$$

$$\langle \nu_\beta^d| = \langle \nu_\beta| + \sum_{\alpha=e,\mu,\tau} \varepsilon_{\alpha\beta}^d \langle \nu_\alpha|, \qquad \text{e.g. } \nu_\tau N \xrightarrow{\varepsilon_{\tau e}^d} e^- X$$

- NC type NSI: Extra matter effects in propagation

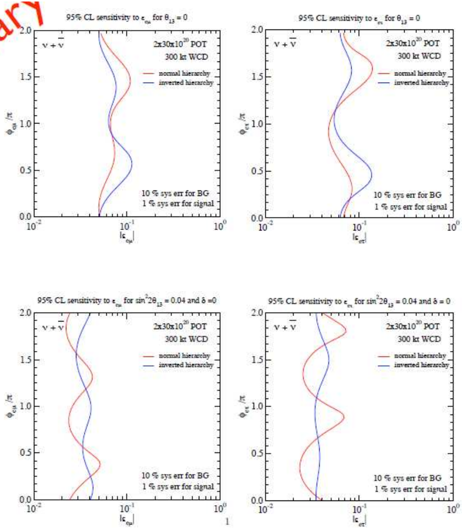
Wolfenstein PR **D17** (1978) 2369, Valle PL **B199** (1987) 432, Guzzo Masiero Petcov PL **B260** (1991) 154, Roulet PR **D44** (1991) R935, etc.

$$(V_{\mathrm{NSI}})_{\alpha\beta} = \sqrt{2} G_F N_e \varepsilon_{\alpha\beta}^m$$

Non Standard Interaction Sensitivities

300 kt WCe, 1MW beam, 3 yrs ν + 3 yrs $\bar{\nu}$

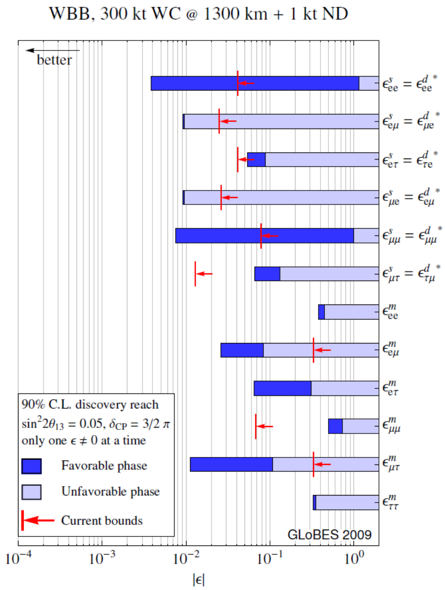
Preliminary



- Hiroshi Nunokawa, SP, Renata Zukanovich-Funchal

Non Standard Interaction Sensitivities

300 kt WCe, 1MW beam, 3 yrs ν + 3 yrs $\bar{\nu}$ Joachim Kopp, FNAL



Bounds can be improved up to one order of magnitude.

Current bounds from arXiv: 0907.0097

Discussion points

- **Need to evaluate running with high energy beam tunes/designs part of the time to access more physics. This impacts beamline design and cost - will movable targets and horns.**
- **How can we improve far detector performance and sensitivity to new physics - such as NSI?**
- **ND physics sensitivity and design - what is BNL's involvment?**